



US Army Research Laboratory



LOW SOLAR ABSORBING CHEMICAL AGENT RESISTANT COATINGS WITH NANO-ADDITIVES

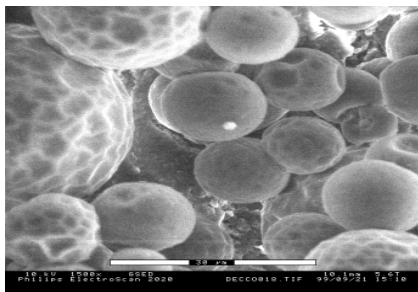
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Courtesy of U.S. Army

- OVERVIEW
- DETAILS OF CHALLENGES
- FORMULATION ELEMENTS
- STATUS



Courtesy of U.S. DoD



Low Solar Absorbing Pigments



Objective:

Provide advance coatings technology that will increase the functionality and durability of Army materiel

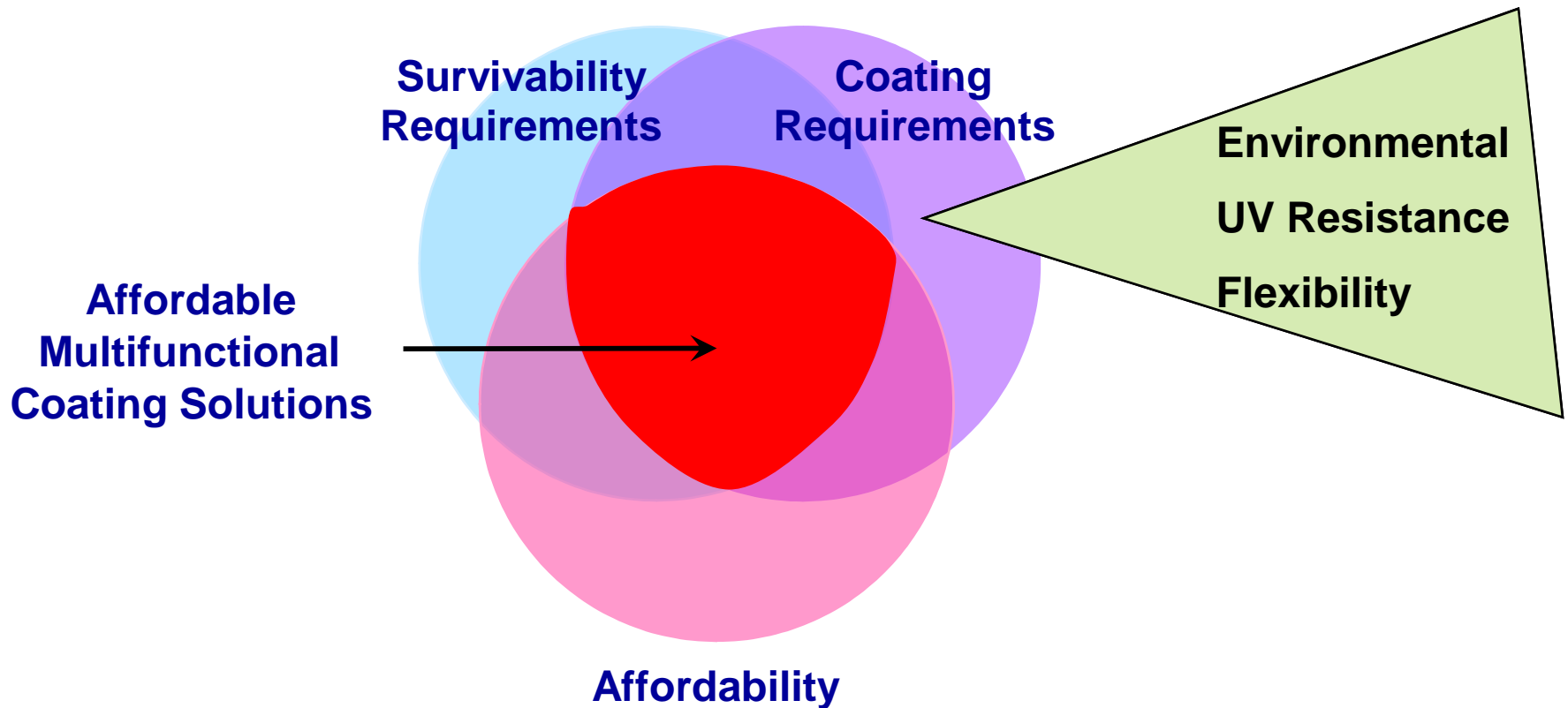


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Increased Options for Balanced Requirements



***New coatings formulations
More Survivable and Durable Platforms***

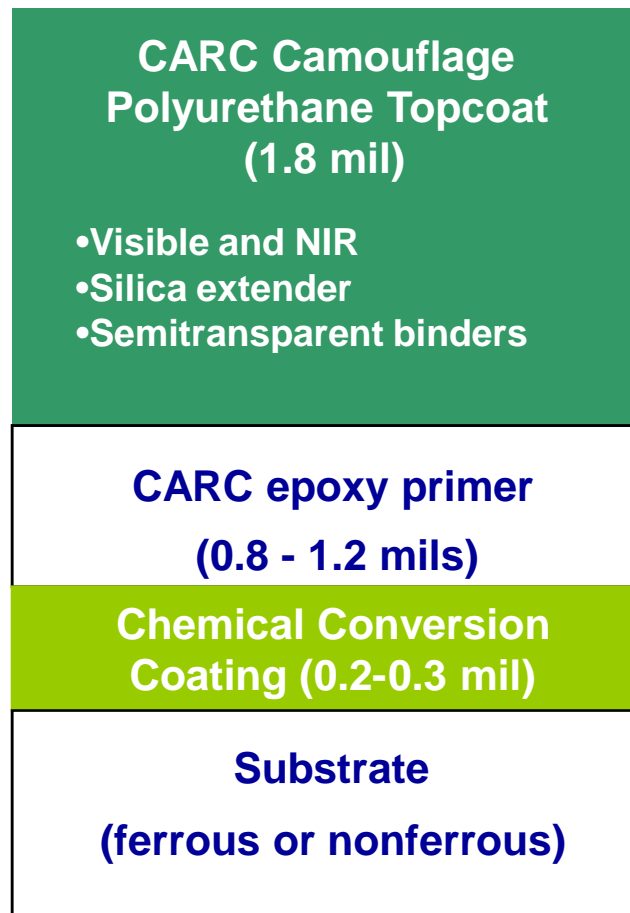


CARC as a System

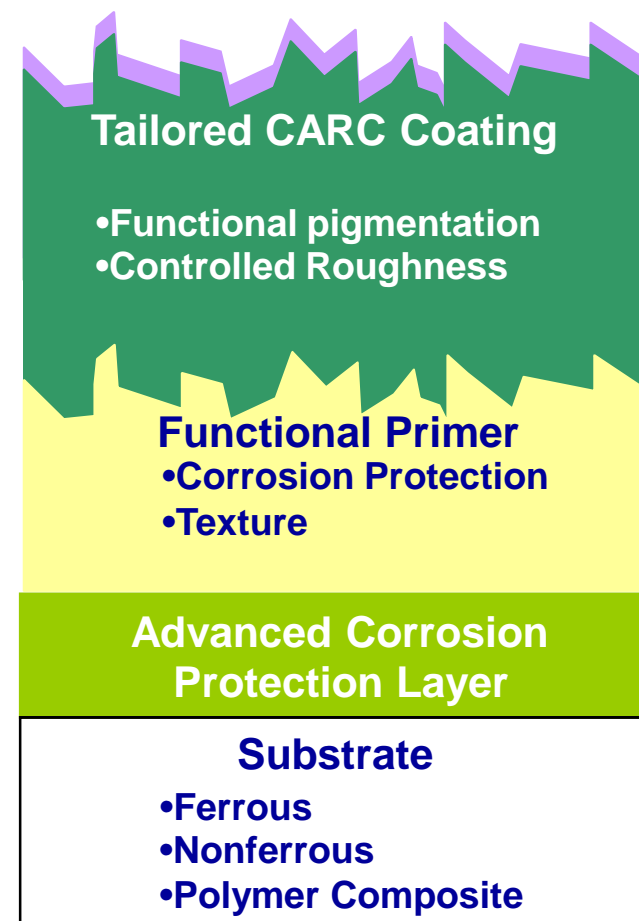


Hierarchical Architecture of Multifunctional Coatings

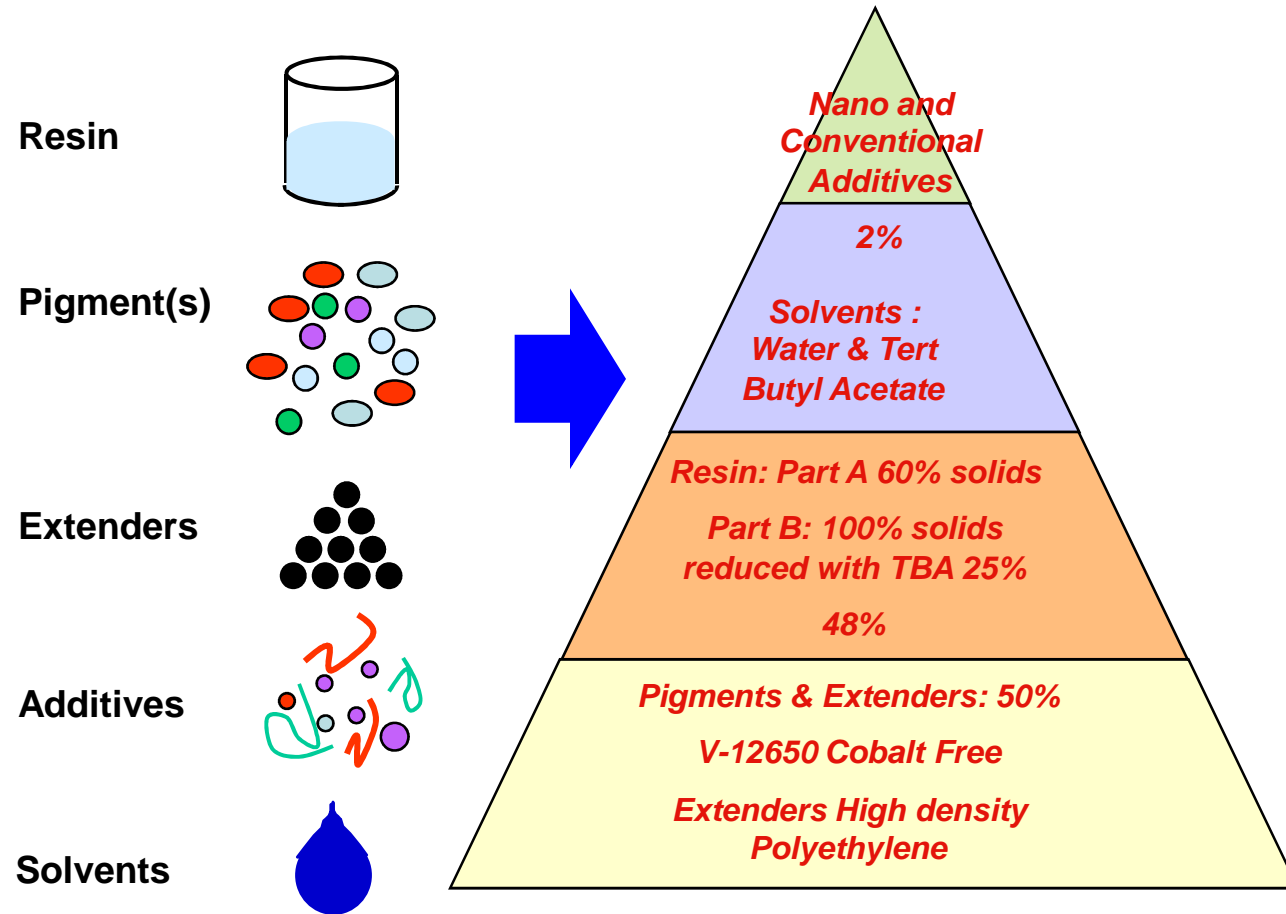
Today



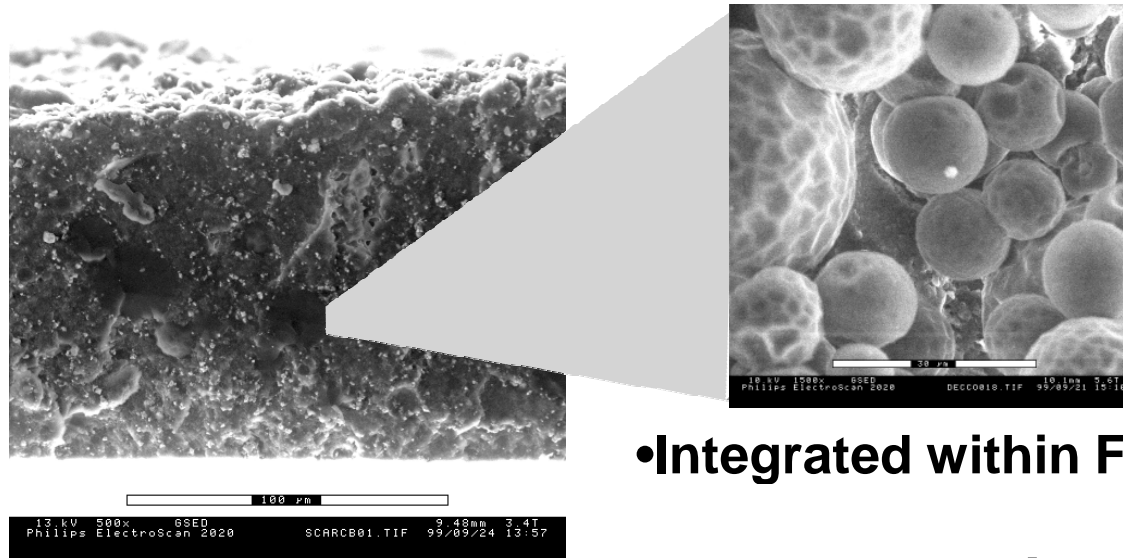
Tomorrow



Individual Coating Components

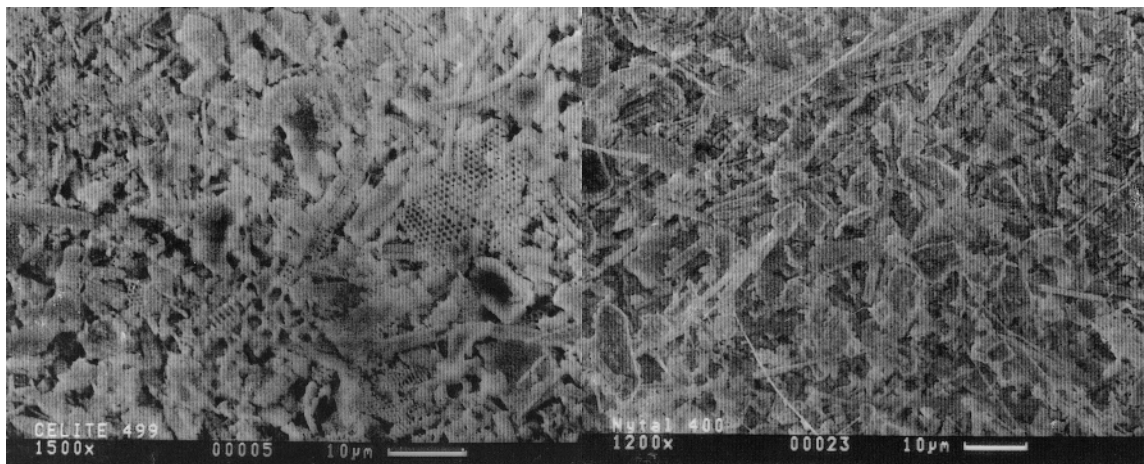


Polymeric beads



• Integrated within Film

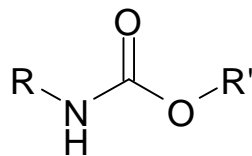
- Polymeric beads
 - Reduce chalking effect
 - Improve UV resistance
 - Improve performance



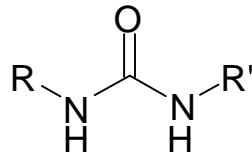
Diatomaceous silica

Talc

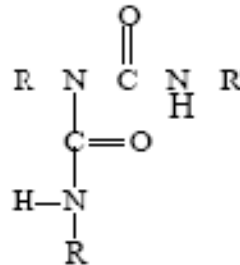
- Unacceptable CAR at $\text{NCO:OH} < 4$
- NMR and FTIR to measure quantify ratio of side products vs. NCO:OH ratio
- Adjust additives, reaction conditions, etc.
 - to make more favorable distribution



Urethane

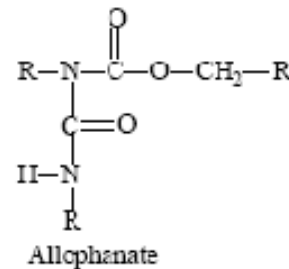


Urea



Bixet

(Urea +
isocyanate)

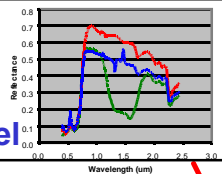


Allophanate

(Urethane
+
isocyanate)

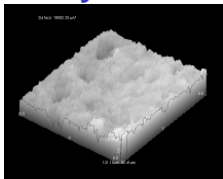
Reflectance

- Specular (gloss)
- Spectral (color)
- Global Exposure Model



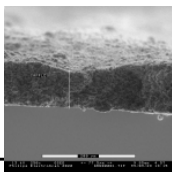
Microscopy

- Physical Changes At Surface
- Failure Analysis



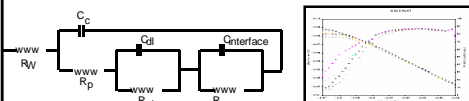
SEM Coating X-section

- Fracture Surface of System
- Constituent Adhesion



Electrochemical Impedance Spectroscopy (EIS)

- Equivalent Circuit Modeling of corrosion behavior

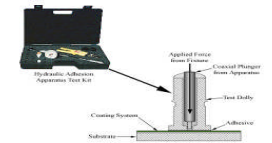


Accelerated Weathering

- Durability, thermal/irradiated
- Degradation, moisture sensitivity

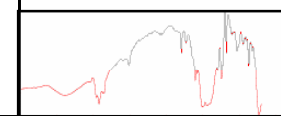
Adhesion Testing

- Durability, flexibility, strength



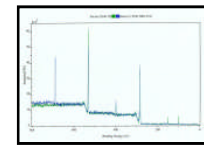
Chemical Structure and Transport Properties

- FTIR/ATR,
- Raman, DGC-MS



SEM-EDX, SAM, XPS, UV-VIS

- Chromium concentrations
- Oxidation states

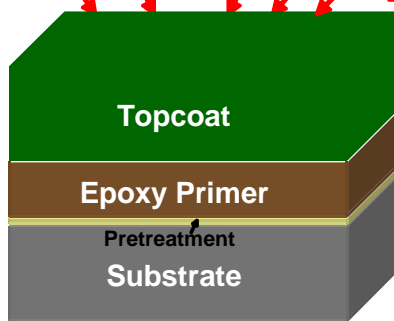


Accelerated Corrosion Testing

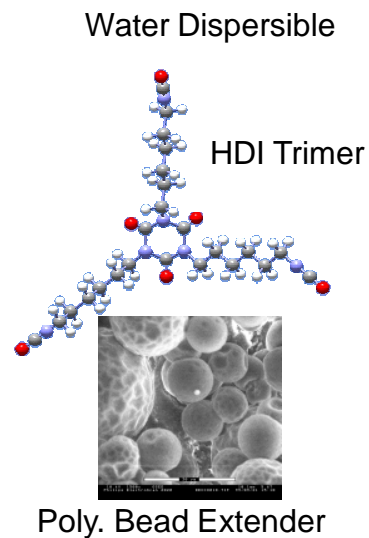
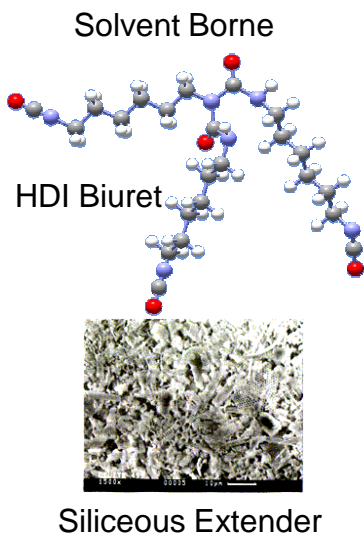
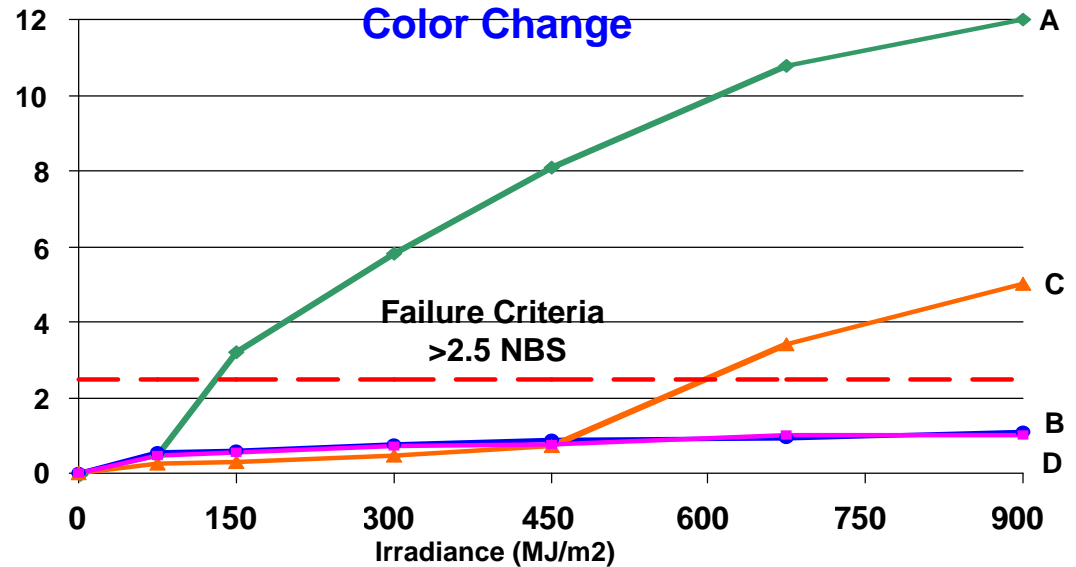
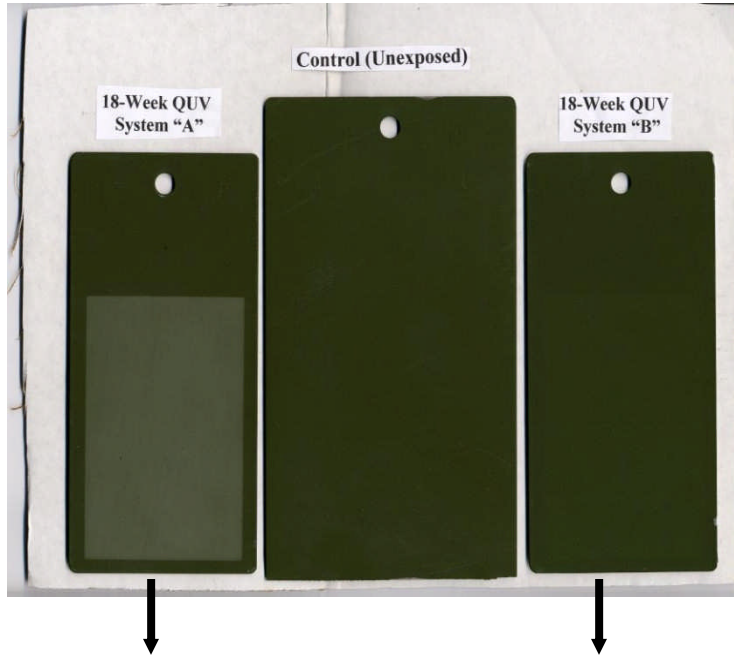
- Permeability, corrosion resistance

DMA, DSC

- T_g, stiffness, crosslink density, extent of cure

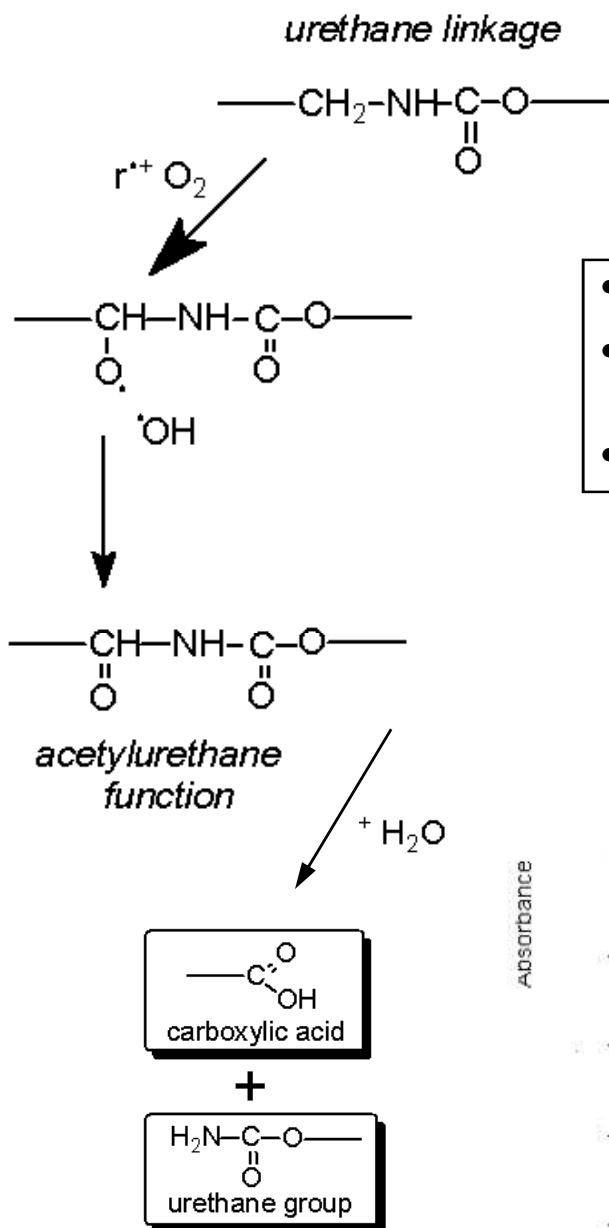


Accelerated UV Degradation

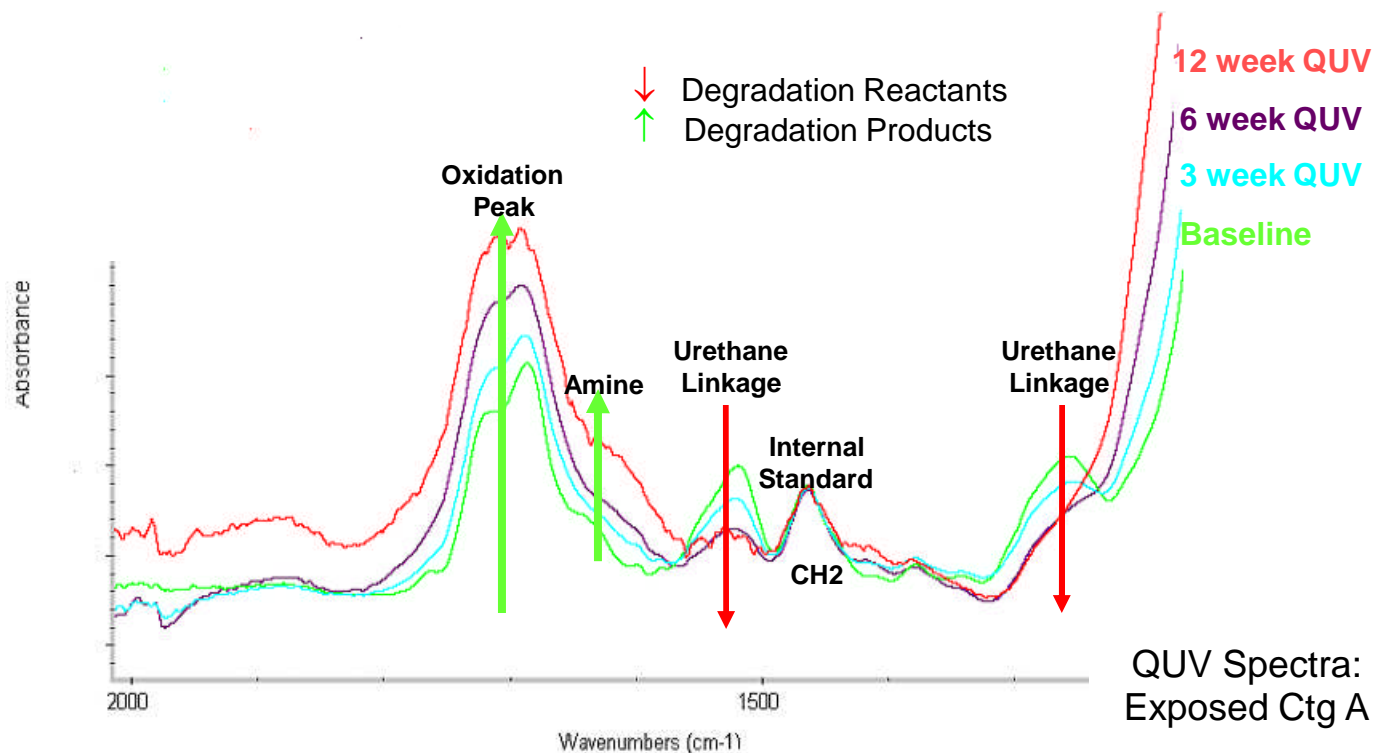


Top Coat	Resin Part A	Resin Part B	Extenders
A Army Green	Saturated Polyester Resin (functional -OH)	HDI Biuret (NCO) 75% resin solids, 25% solvent	Siliceous
B Army Green	Hydroxyl Functional PU Water Dispersible	Modified HDI Trimer Waterborne	Polymeric Beads
C Nav/Air Grey	Saturated Polyester Resin	HDI Trimer 75% resin solids, 25% solvent	Siliceous w./fluoro additives
D Nav/Air Grey	Conventional Polyester: 100% solid (low MW)	Blend of HDI Trimers 100% solid	Siliceous w./fluoro additives

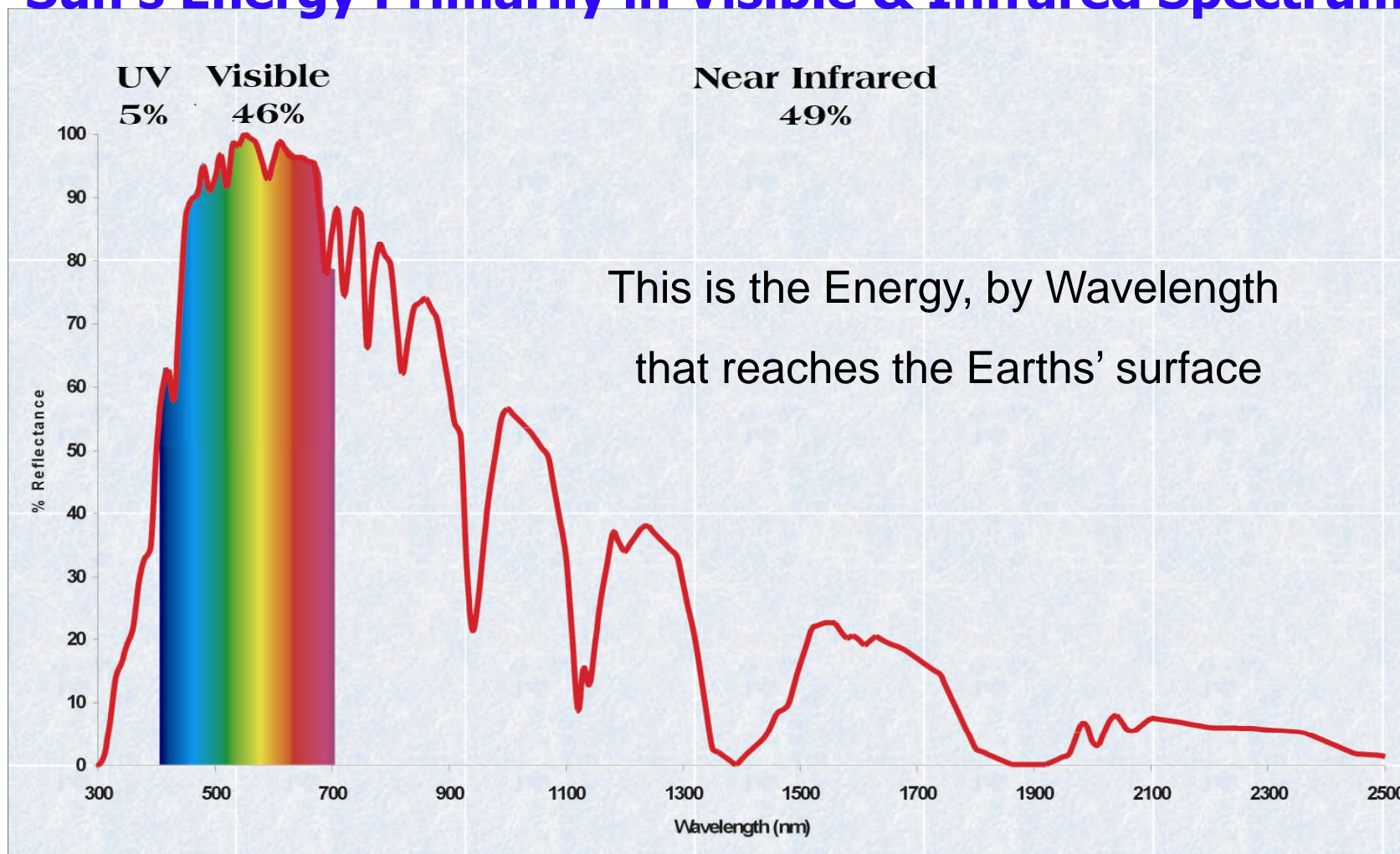
Photo Oxidation Mechanism Proposed & Verified



- Urethane linkages act as MCS binder
- Chain scission of urethane linkage in presence of UV irradiation & oxygen
- Degradation reactants & products are tracked by ATR-IR

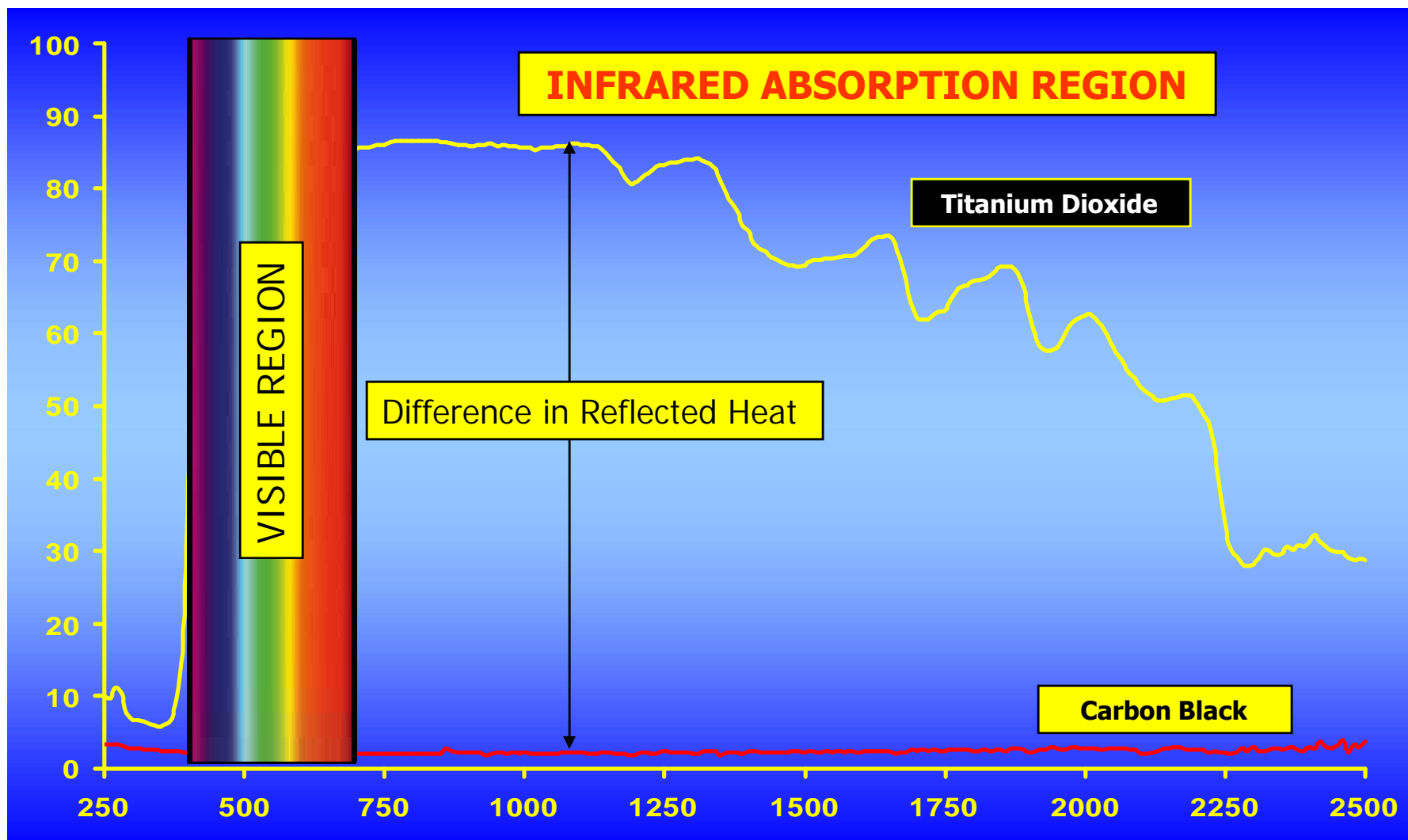


Sun's Energy Primarily in Visible & Infrared Spectrum





Reflectance Values of TiO₂ versus Carbon Black over the range of Solar Radiance

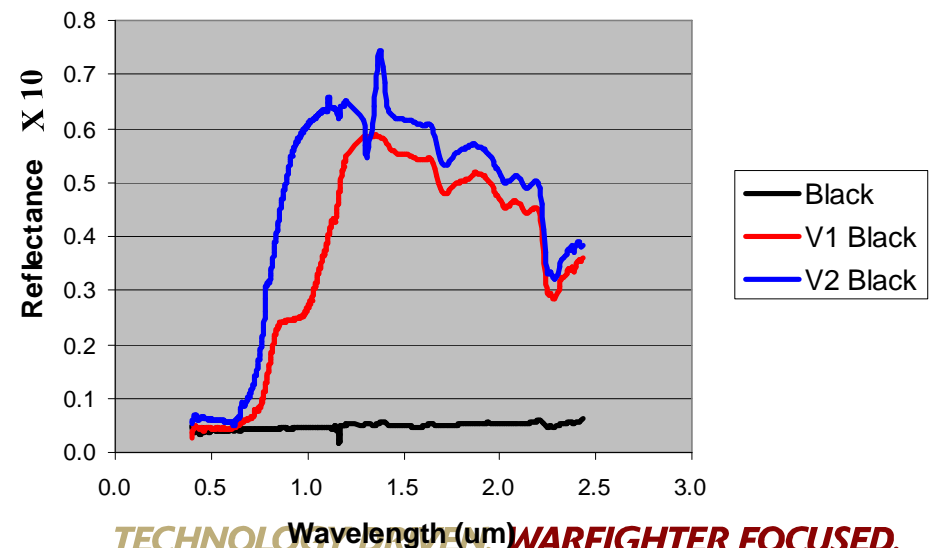
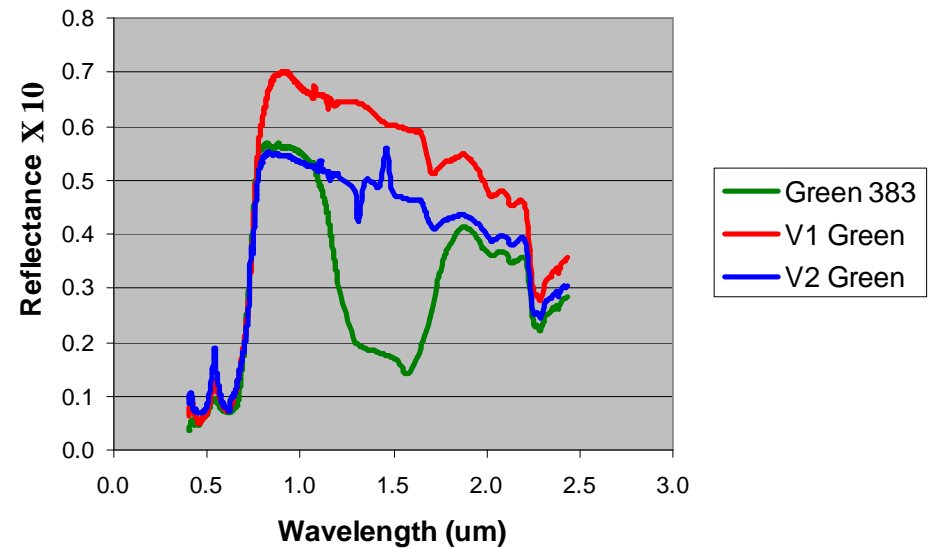




Low Solar Absorbing Coatings

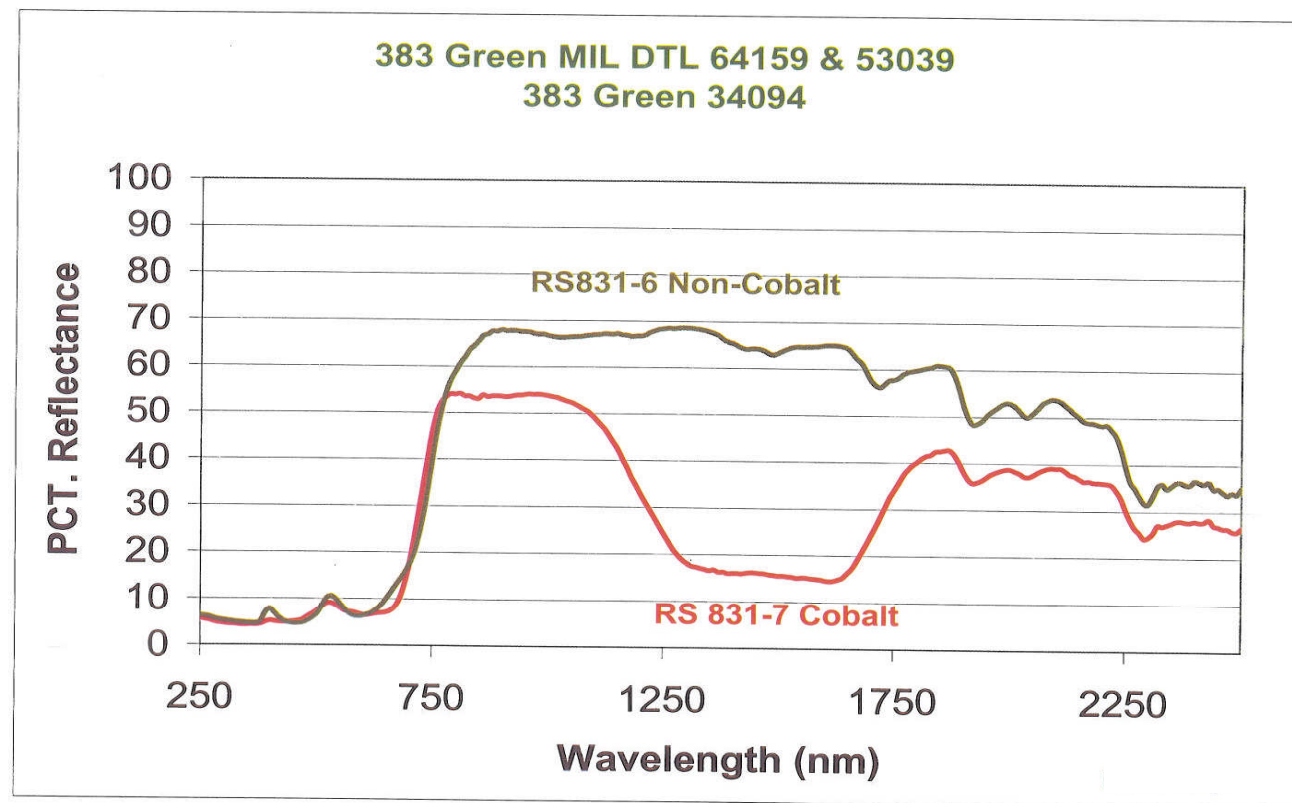


- ❖ Visually identical colors
- ❖ Higher Reflectance lower Temperature
- ❖ Reduce current coatings surface temperatures 20 to 50 Fahrenheit
- ❖ Major reductions in sustainability cost with extended coating life and with lower operating temperatures





Low Solar Absorbing CARC





Low Solar Absorbing CARC



- 2 year weathering excellent: Less than 1 color unit change
- Formulated four Primary Colors
- IR requirements will shift from 380nm -900nm to 380nm-2000nm with emphasis on 750nm to 1700nm.
- Visible unchanged
- Key highlight: COST, cobalt spinal increase of 300% and availability erratic
- Formulation will be cobalt free for 383 Green, AC Green, 383 Brown
- 383 Green to change to 808 Green to identify change
- Open to other approaches*



Low Solar Absorbing CARC



- ❖ 808 Green will be introduced as a new color this calendar year
- ❖ Specifics for IR and Color space will be provided to vendors and acceptance will be verified for all vendors prior to QPD issue



Acknowledgements



Co-Authors:

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- Kenneth T. Loye, FERRO Corporation

➤ ARL Technical Support:

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- Nick Nesteruk
- Dan Pope
- Wendy Kosik
- Dawn Crawford



Corrosion Resistant Materials for Armor

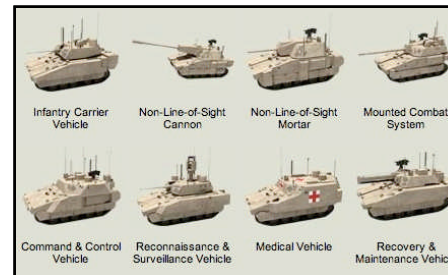


Aluminum Alloy 5059 For Armor Applications Foreign Comparative Test Program

- Updated military AI armor specification MIL-DTL-46027K
- Over \$14M to date in acquisition
 - \$12M+ in direct procurement of AA5059 for RG-33 MRAP
 - Over \$1.1M of acquisition by OEMs for internal testing, design, and prototyping
 - AA5059-H131 chosen as primary (100%) common hull material for all 8 variants of the PM FCS-BCT Manned Ground Vehicle (MGV) by Boeing (LSI), General Dynamics, and BAE Systems



MRAP RG-33



(8) MGV Mission Based Variants



- Related work - military specification MIL-DTL-32262 created for 6061 Al